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No. 6329-6

## DEVELOPMENT OF METALLIZATION PROCESS

For the Period Ending

September 30, 1982

Contract 956205

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The Flat-Plate Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

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#### ABSTRACT/SUMMARY

Solar cells without AR coating achieved efficiencies of 10.5% with the Type A Mo/Sn/TiH paste. Curve shape, series resistance, and shunt resistance are all excellent and comparable to silver paste controls. Other pastes were not successful.

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## Section 1.0

### INTRODUCTION

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The objective of this contract is the optimization, evaluation, and demonstration of a novel metallization applied by a screen printing process. The process will be evaluated on both CZ and non-CZ silicon wafers.

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## Section 2.0

### TECHNICAL DISCUSSION

Procurement delays and vendor error delayed the receipt of square pattern screens. The inefficient round pattern was used to test additional paste formulation.

The pastes are 80-85% solids using vehicle #3347. The metal content in parts by weight follows:

Type	TFS #	Sylvania 280-325 Mo	Atlantic Equipment Engineers SN 266 Sn	Ferro Plant PX-41 TiH
A	DP-E570	19.5	80.0	0.5
B	DP-E571	50.0	49.5	0.5
C	DP-E572	70.0	29.5	0.5
D	DP-E573	49.0	49.0	2.0
E	DP-E574	48.0	48.0	4.0

Eight cells of each paste type as well as silver controls were manufactured. The cells of each type were divided into four groups (of 2 each). The four groups were processed as follows:

- 1) 18"/1 min. 500°C prefire, 1 min. 575°C H<sub>2</sub> fire
- 2) 18"/min. 500°C prefire, 1 min. 600°C H<sub>2</sub> fire
- 3) 9"/min. 500°C prefire, 1 min. 575°C H<sub>2</sub> fire
- 4) 9"/min. 500°C prefire, 1 min. 600°C H<sub>2</sub> fire

The results of this matrix are shown in Table 1. The best silver control had  $V_{oc} = 601$ ,  $I_{sc} = 700$ ,  $I_{500} = 500$ , and  $I_{450} = 586$ .

Table 1

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Paste Type	Pre-Fire Speed @ 500°	Fire Temp. @ 1 min.	Cell #	V <sub>oc</sub>	I <sub>sc</sub>	I <sub>500</sub>	I <sub>450</sub>
A	9"	575	1	600	701	482	569
A	9"	575	2	598	677	390	490
A	9"	600	3	601	700	469	553
A	9"	600	4	597	696	458	548
A	18"	575	5	603	702	450	543
A	18"	575	7	599	560	286	359
A	18"	600	6	598	701	440	530
A	18"	600	8	602	703	461	550
B	9	575	9	600	687	377	488
B	9	575	11	598	676	297	398
B	9	600	10	600	689	369	478
B	9	600	12	597	644	282	371
B	18	575	13	602	681	345	451
B	18	575	14	602	681	331	438
B	18	600*	15	598	686	409	515
B	18	600*	16	596	692	389	497
C	9	575	20	594	617	194	266
C	9	575	17	589	369	109	150
C	9	600	19	592	668	246	345
C	9	600	18	587	300	90	123
C	18	575	21	597	684	305	415
C	18	575	23	598	667	285	388
C	18	600	22	600	687	350	463
C	18	600	24	596	680	347	453
D	9	575	26	598	684	330	447
D	9	575	25	599	681	320	429
D	9	600	28	598	676	328	435
D	9	600	27	599	678	351	455
D	18	575	31	596	686	346	464
D	18	575	29	598	682	336	448
D	18	600	32	601	691	378	441
D	18	600	30	600	694	393	502
E	9	575	33	596	668	260	356
E	9	575	34	596	639	229	312
E	9	600	35	596	674	265	363
E	9	600	36	598	677	262	417
E	18	575	37	597	672	295	396
E	18	575	38	598	669	286	385
E	18	600	39	597	690	333	440
E	18	600	40	600	685	318	420

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These cells have no AR coating. The best silver solar cell has an efficiency of 9.3% and a fill factor of 0.627. The best Mo/Sn, Cell #1 from Group A has a fill factor of 0.609 and an efficiency of 9.0%. If the cells were AR coated, efficiency would rise to ~ 12.3% and 11.9% respectively.

From these results it was decided to continue work using only Type A paste. Four-inch screens were received but were of poor quality. Additional screens were ordered.

A lot of cells was processed using the screens. The front pattern metallization is shown in Figure 1. Cells were prefired at 500-550°C at a belt speed of 18" minutes. They were then fired at 575°-625° for 39-90 seconds. Silver controls were processed at the same time.

Figures 2 and 3 show the best Mo/Sn and Ag cells. The Mo/Sn cell was made using paste Type A with a 200 mesh 1 mil emulsion screen. The Ag cell was made with the same screen. The Mo/Sn cell was prefired at 500°C in an 18" zone at 18"/min. belt speed. It was then fired in H<sub>2</sub> for 90 seconds at 600°C.

The Mo/Sn metallization has a blue-gray color after the prefire which becomes metallic after firing similar to screen-printed silver. If the prefire is at a lower temperature, the initial color is brown and cells show more series resistance.

The two cells shown in Figure 2 have the following characteristics:

Cell	$V_{oc}$	$I_{sc}$	$I_{500}$	$P_{max}$	FF	E
1728M-90 (Mo/Sn)	.601	.678	.596	.229	.73	10.5%
1728M-72 (Ag)	.601	.680	.600	.302	.74	10.6%

Neither cell has an AR coating.



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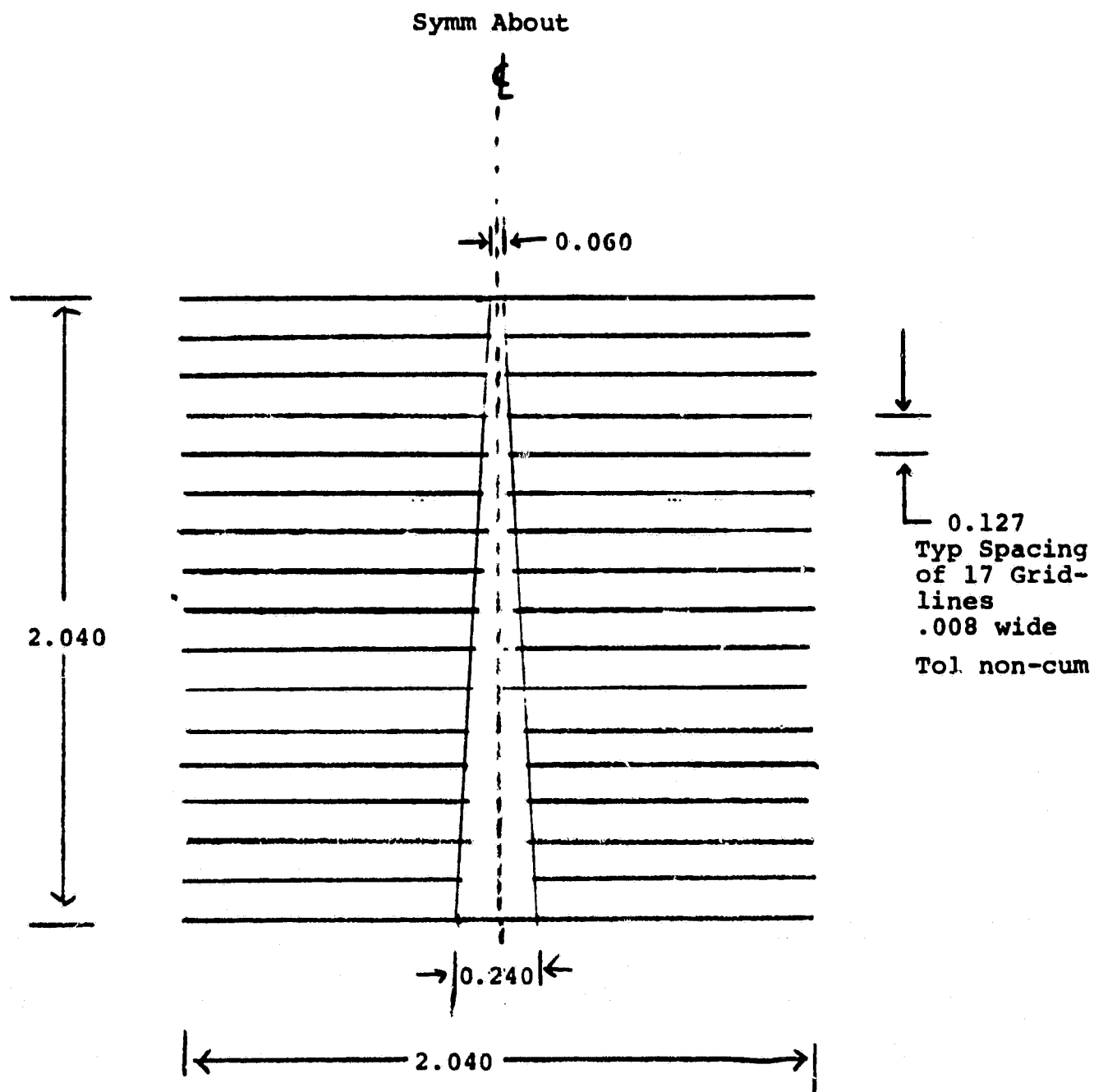


Figure 1  
FRONT METALLIZATION PATTERN

Figure 2

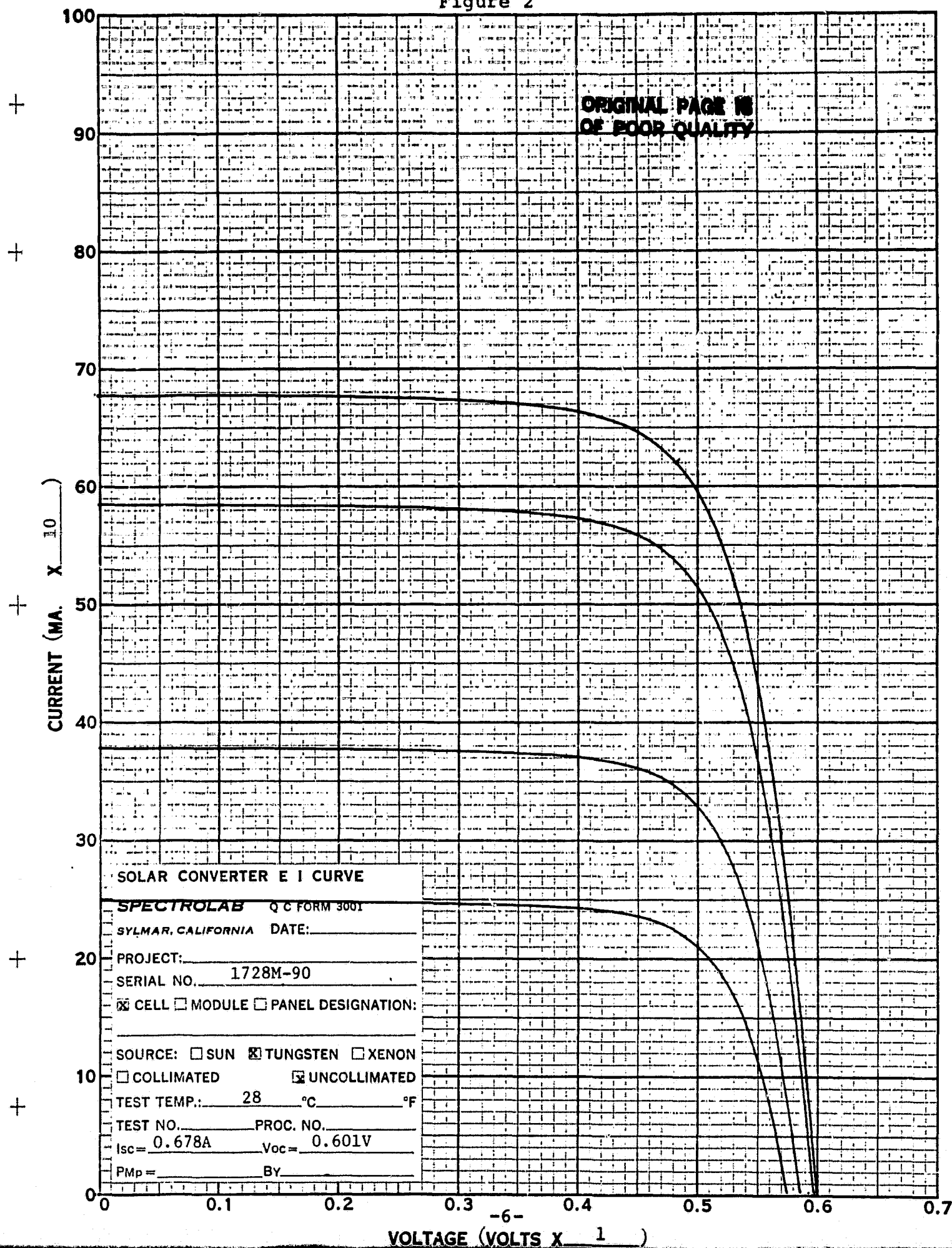
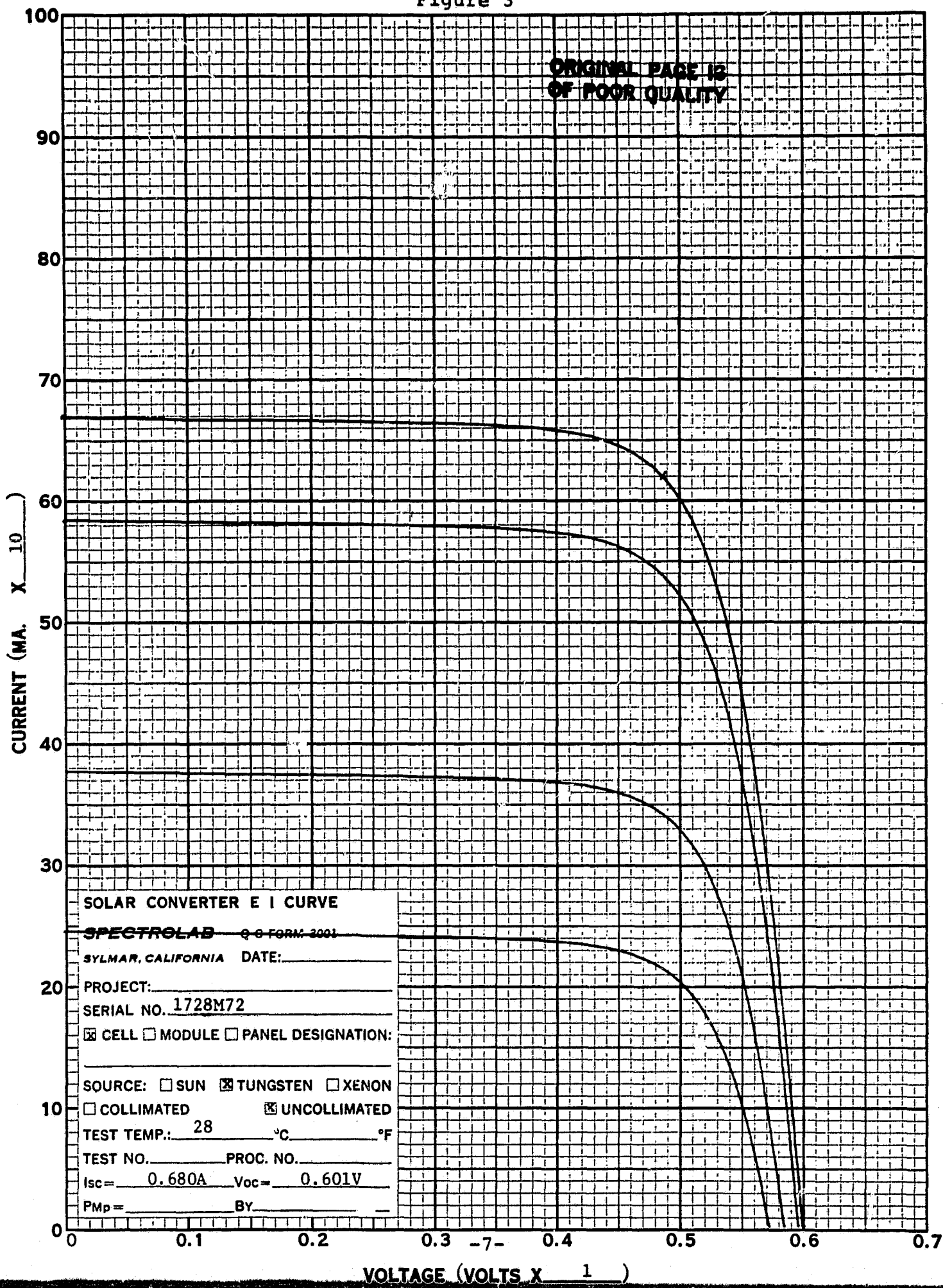


Figure 3

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### Section 3.0

#### CONCLUSIONS AND RECOMMENDATIONS

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Work will continue exclusively on the Type A paste. Cells made with this paste have characteristics almost identical to silver paste cells.

## Section 4.0

### ACTIVITIES PROJECTION

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At the request of JPL the contract was redirected to include the evaluation of indium tin oxide (ITO) conductive AR coatings. This evaluation necessitated a no-cost extension of the contract. A new Milestone Chart and Deliverable Schedule is shown on the following page.

